

## 4.2 PIPES, OUTFALLS, AND PUMPS

This section presents the methods, criteria, and details for analysis and design of pipe systems, outfalls, and pump-dependent conveyance systems. The information presented is organized as follows:

- Section 4.2.1, "Pipe Systems"
  - "Design Criteria," Section 4.2.1.1
  - "Methods of Analysis," Section 4.2.1.2 (p. 4-19)
- Section 4.2.2, "Outfall Systems"
  - "Design Criteria," Section 4.2.2.1 (p. 4-29)
- Section 4.2.3, "Pump Systems"
  - "Design Criteria," Section 4.2.3.1 (p. 4-36)
  - "Methods of Analysis," Section 4.2.3.2 (p. 4-36)

### 4.2.1 PIPE SYSTEMS

*Pipe systems* are networks of storm drain pipes, catch basins, manholes, inlets, and outfalls designed and constructed to convey surface water. The hydraulic analysis of flow in storm drain pipes typically is limited to gravity flow; however, in analyzing existing systems it may be necessary to address pressurized conditions. A properly designed pipe system will maximize hydraulic efficiency by utilizing proper material, slope, and pipe size.

#### 4.2.1.1 DESIGN CRITERIA

##### General

All pipe material, joints, and protective treatment shall be in accordance with Section 9.05 of the *WSDOT/APWA Standard Specifications* as modified by the *King County Road Standards* and AASHTO and ASTM treatment as noted below under "Allowable Pipe Materials."

*Note: The pipe materials and specifications included in this section are for conveyance systems installed according to engineering plans required for King County permits/approvals. Other pipe materials and specifications may be used by private property owners for drainage systems they construct and maintain when such systems are not required by or granted to King County.*

##### Acceptable Pipe Sizes

The following pipe sizes shall be used for **pipe systems to be maintained by King County**: 8-inch (generally for use only in privately maintained systems or in special cases within road right-of-way; see *KCRS*), 12-inch, 15-inch, 18-inch, 21-inch, 24-inch, and 30-inch. For pipes larger than 30-inch diameter, increasing increments of 6-inch intervals shall be used (36-inch, 42-inch, 48-inch, etc.).

##### Allowable Pipe Materials

The following pipe materials are allowed for use in meeting the requirements of this manual. Refer to WSDOT/APWA 7-04 and 9-05 for detailed specifications for acceptable pipe materials. Refer to the *King County Road Standards (KCRS)* for pipe materials allowed in King County road right-of-way.

1. Plain and reinforced concrete pipe
2. Corrugated or spiral rib aluminum pipe

3. Corrugated steel pipe, Aluminized or Galvanized<sup>2</sup> with treatments 1 through 6
4. Spiral rib steel pipe, Aluminized or Galvanized with treatments 1 through 6
5. Ductile iron (water supply, Class 50 or 52)
6. Lined corrugated polyethylene pipe (LCPE)<sup>3</sup>
7. Corrugated polyethylene pipe (CPE)<sup>4</sup> that is single wall and fully corrugated
8. Polyvinyl chloride (PVC)<sup>5</sup> pipe
9. Solid wall polyethylene pipe (SWPE; also known as HDPE pipe or HDPP)<sup>6</sup>

### **Allowable Pipe Joints**

1. Concrete pipe shall be rubber gasketed.
2. CMP shall be rubber gasketed and securely banded.
3. Spiral rib pipe shall be "hat-banded" with neoprene gaskets.
4. Ductile pipe joints shall be flanged, bell and spigot, or restrained mechanical joints.
5. LCPE pipe joints shall conform to the current *WSDOT/APWA Standard Specifications*.
6. CPE single wall, fully corrugated pipe joints shall conform to the current *WSDOT/APWA Standard Specifications*.
7. PVC pipe shall be installed following procedures outlined in ASTM D2321; joints shall conform to ASTM D3212, and gaskets shall conform to ASTM F477.
8. SWPE pipe shall be jointed by butt fusion methods or flanged according to the *KCRS*.

---

<sup>2</sup> Galvanized metals leach zinc into the environment, especially in standing water situations. High zinc concentrations, sometimes in the range that can be toxic to aquatic life, have been observed in the region. Therefore, use of galvanized materials should be avoided. Where other metals, such as aluminum or stainless steel, or plastics are available, they shall be used. If these materials are not available, asphalt coated galvanized materials may then be used.

<sup>3</sup> LCPE pipe and fittings shall be manufactured from high density polyethylene resin which shall meet or exceed the requirements of Type 111, Category 3, 4 or 5, Grade P23, P33 or P34, Class C per ASTM D1248. In addition, the pipe shall comply with all material and stiffness requirements of AASHTO M294.

<sup>4</sup> CPE pipe (single wall, fully corrugated) is allowed only for use in private storm sewer systems such as downspout, footing, or yard drain collectors on private property (smooth interior required in road right-of-way for drainage stub-outs or perforated as subgrade drain per *KCRS*).

<sup>5</sup> PVC pipe is allowed only for use in privately maintained drainage systems or as allowed in road right-of-way per *KCRS*. PVC pipe must be SDR 35 or thicker and meet the requirements of ASTM D3034.

<sup>6</sup> SWPE pipe is normally used outside of King County right-of-way, such as on steep slope installations (see Section 4.2.2, p. 4-29). Connections to King County road drainage systems are allowed for pipe diameters of 12" or greater. SWPE pipe shall comply with the requirements of Type III C5P34 as tabulated in ASTM D1248, shall have the PPI recommended designation of PE3408, and shall have an ASTM D3350 cell classification of 345534C. The pipe shall have a manufacturer's recommended hydrostatic design stress rating of 800 psi based on a material with a 1600 psi design basis determined in accordance with ASTM D2837-69. The pipe shall have a suggested design working pressure of 50 psi at 73.4° F and SDR of 32.5.

## 4.3 CULVERTS AND BRIDGES

This section presents the methods, criteria, and details for hydraulic analysis and design of culverts and bridges. The information presented is organized as follows:

- Section 4.3.1, "Culverts"
  - "Design Criteria," Section 4.3.1.1 (p. 4-37)
  - "Methods of Analysis," Section 4.3.1.2 (p. 4-39)
- Section 4.3.2, "Culverts Providing for Fish Passage/Migration"
  - "Design Criteria," Section 4.3.2.1 (p. 4-51)
  - "Methods of Analysis," Section 4.3.2.2 (p. 4-52)
- Section 4.3.3, "Bridges"
  - "Design Criteria," Section 4.3.3.1 (p. 4-53)
  - "Methods of Analysis," Section 4.3.3.2 (p. 4-54).

### 4.3.1 CULVERTS

*Culverts* are relatively short segments of pipe of circular, elliptical, rectangular, or arch cross section. They are usually placed under road embankments or driveways to convey surface water flow safely under the embankment. They may be used to convey flow from constructed or natural channels including streams. The Critical Areas Code (KCC 21A.24) contains definitions of streams (termed "aquatic areas") and requirements for crossing of streams. In addition to those requirements and the design criteria described below, other agencies such as the Washington State Department of Fish and Wildlife (WDFW) may have additional requirements affecting the design of proposed culverts.

#### 4.3.1.1 DESIGN CRITERIA

##### General

1. All **circular pipe culverts** shall conform to any applicable design criteria specified for pipe systems in Section 4.2.1.
2. All **other types** of culverts shall conform to manufacturer's specifications. See the *King County Road Standards* and *General Special Provisions* for types of culverts allowed in King County right-of-way.

##### Headwater

1. For **culverts 18-inch diameter or less**, the maximum allowable headwater elevation (measured from the inlet invert) shall not exceed 2 times the pipe diameter or arch-culvert-rise at *design flow* (i.e., the 10-year or 25-year peak flow rate as specified in Core Requirement #4, Section 1.2.4).
2. For **culverts larger than 18-inch diameter**, the maximum allowable design flow headwater elevation (measured from the inlet invert) shall not exceed 1.5 times the pipe diameter or arch-culvert-rise at design flow.
3. The **maximum headwater elevation** at design flow shall be below any road or parking lot subgrade.

### Inlets and Outlets

1. All inlets and outlets in or near roadway embankments must be flush with and conforming to the slope of the embankment.
2. For culverts 18-inch diameter and larger, the embankment around the culvert inlet shall be protected from erosion by **rock lining or riprap** as specified in Table 4.2.2.A (p. 4-31), except the length shall extend at least 5 feet upstream of the culvert, and the height shall be at or above the design headwater elevation.

**Inlet structures**, such as concrete headwalls, may provide a more economical design by allowing the use of smaller entrance coefficients and, hence, smaller diameter culverts. When properly designed, they will also protect the embankment from erosion and eliminate the need for rock lining.

3. In order to maintain the stability of roadway embankments, concrete headwalls, wingwalls, or tapered inlets and outlets may be required if **right-of-way or easement constraints** prohibit the culvert from extending to the toe of the embankment slopes. All inlet structures or headwalls installed in or near roadway embankments must be flush with and conforming to the slope of the embankment.
4. **Debris barriers (trash racks)** are required on the inlets of all culverts that are over 60 feet in length and are 18 to 36 inches in diameter. Debris barriers shall have a bar spacing of 6 inches. This requirement also applies to the inlets of pipe systems. See Figure 4.2.1.D (p. 4-17) and Figure 4.2.1.E (p. 4-18) for debris barrier details.
5. For culverts 18-inch diameter and larger, the receiving channel of the outlet shall be protected from erosion by **rock lining** specified in Table 4.2.2.A (p. 4-31), except the height shall be one foot above maximum tailwater elevation or one foot above the crown, whichever is higher (See Figure 4.2.2.M, p. 4-32).